EDDI

Electronic Drawbar - Digital Innovation

Project report - presentation of the results

HOCHSCHULE FRESENIUS UNIVERSITY OF APPLIED SCIENCES · DB SCHENKER · MAN

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EDDI – Electronic Drawbar – Digital Innovation

Project report – presentation of the results

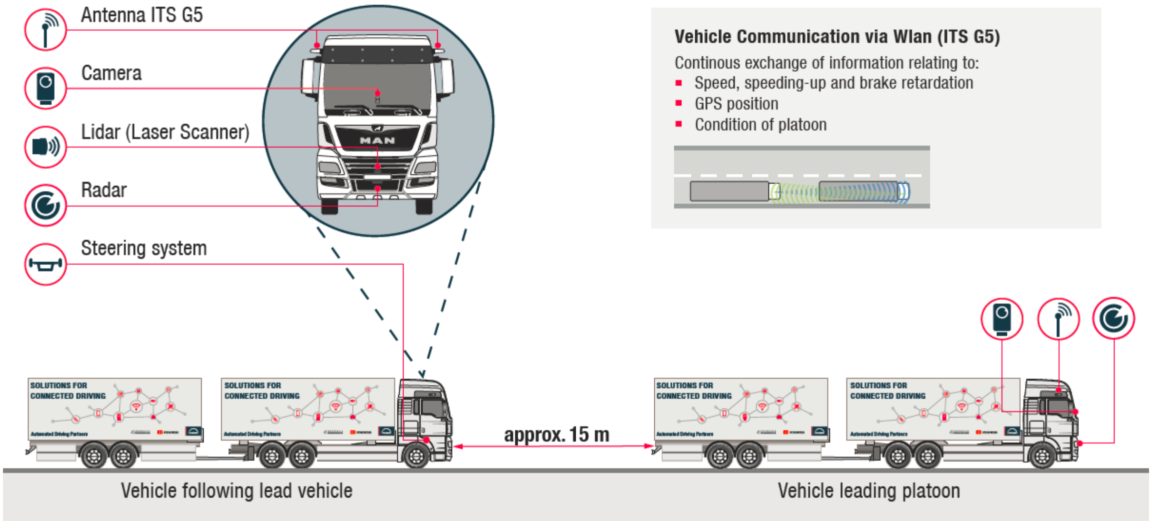
For the first time anywhere in the world, truck platoons went into practical operation in June 2018 as part of the "Electronic Drawbar – Digital Innovation", EDDI for short, project funded to the tune of two million euros by the Federal Ministry of Transport and Digital Infrastructure (BMVI). This joint project is run by MAN Truck & Bus, DB Schenker and the Hochschule Fresenius. Multiple aspects caused a worldwide stir from the outset: Having two electronically linked trucks on a highway under real traffic conditions providing logistics services over a long period was unprecedented. And this was the first time that professional drivers rather than test drivers were at the wheel of the trucks.

Platooning in this case refers to a system that vehicles use on the road in which at least two trucks drive in a tight convoy on a highway, supported by technical driving assistance and control systems. All of the vehicles in the platoon are linked to each other by an electronic "drawbar" that uses vehicle-to-vehicle communication. The truck in front sets the speed and direction, and the others follow. The advantage of the technology lies, on the one hand, in the slipstream effect that allows the following vehicle to drive more efficiently. On the other, the electronically linked vehicles respond as a single unit, which enhances safety. In particular, platooning helps make better use of the existing road space. MAN fitted two volume-production truck chassis with the platooning technology for the pilot. Both vehicles are identical and can each perform the role of lead or following vehicle. The vehicles are equipped with state-of-the-art assistance and safety systems.

Types of technical equipment

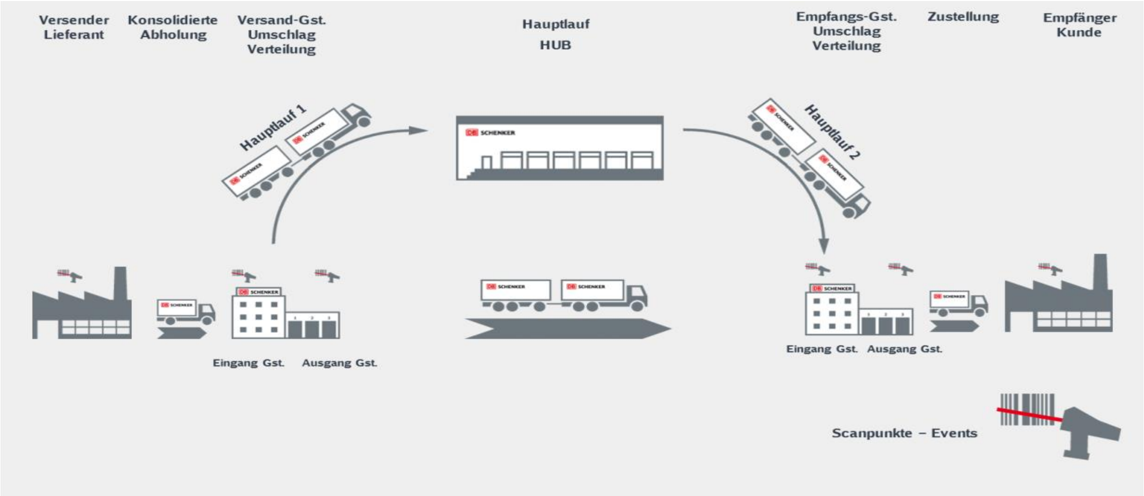
Volume-production equipment includes the adaptive cruise control (ACC) and the Emergency Brake Assist (EBA). The aerials for the vehicle-to-vehicle communication are located above the doors on the cab. A protocol based on WLAN11p (ITS G5), which MAN developed in-house, is used. In addition to the standard-fit radar and camera sensor, MAN has fitted a Lidar (Light Detection and Range) sensor in the platooning vehicles, which, thanks to its large aperture angle, can detect early on vehicles that may potentially cut in. The standard-fit radar and standard-fit camera provide the distance proximity function. MAN uses an electrically controllable steering system for lateral guidance in the following vehicle. To implement the safety concept required for the test drives, MAN has configured the relevant vehicle systems redundantly. This includes a foot brake module which also electrically drives the pneumatic restraint circuit depending on the platooning state. Standard-fit braking system and the standard-fit Emergency Brake Assist were modified for use during a platoon run. A safety control unit interacts with all the involved components and manages the acceleration and deceleration requirements. It only then releases the platooning mode if all of the components are working correctly. This vehicle architecture ensures that the vehicle also brakes reliably should individual components fail. Both vehicles feature an innovative full-TFT display, which permanently displays the platooning operating data. Modified steering wheels are also used, which have been supplemented with activation buttons for the platooning function in addition to the standard-fit onboard-computer and cruise-control operating functions.

Equipped in this way, the cooperation partners operated the project vehicles in platooning mode on the basis of the exemption certificate from the responsible Bavarian Ministry of the Interior, Sport and Integration on the Digital Test Bed A9 highway between Munich and Nuremberg. The distance between the vehicles was around 15 meters during the platoon run. The exemption certificate specified the breakup of the platoon at highway junctions, ahead of roadworks, on uphill and downhill gradients of over 4%, accident scenes and very heavy traffic. The top speed was also set to 80 km/h.



Actual goods transportation in the groupage network

From August through December 2018, first dummy weights and then actual goods from DB Schenker's European groupage network were transported using a platoon setup. The DB Schenker Munich branch responsible for these shipments modified the timetable in the groupage network after analyzing the logistics systems and journeys, and initially tested the departure times of the platooning shipments with two standard trucks from early September. The consignments on the platooning trucks constitute the main run in the groupage network between these two branches. At present multiple runs ply between Munich and Nuremberg every day so that no extra journey had to be implemented for the platoon. This ensured comparability with transporting existing consignments – say in relation to goods provisioning and vehicle dispatching. It became apparent that it was possible to bundle goods and provide the swap bodies for actual platoon journeys.

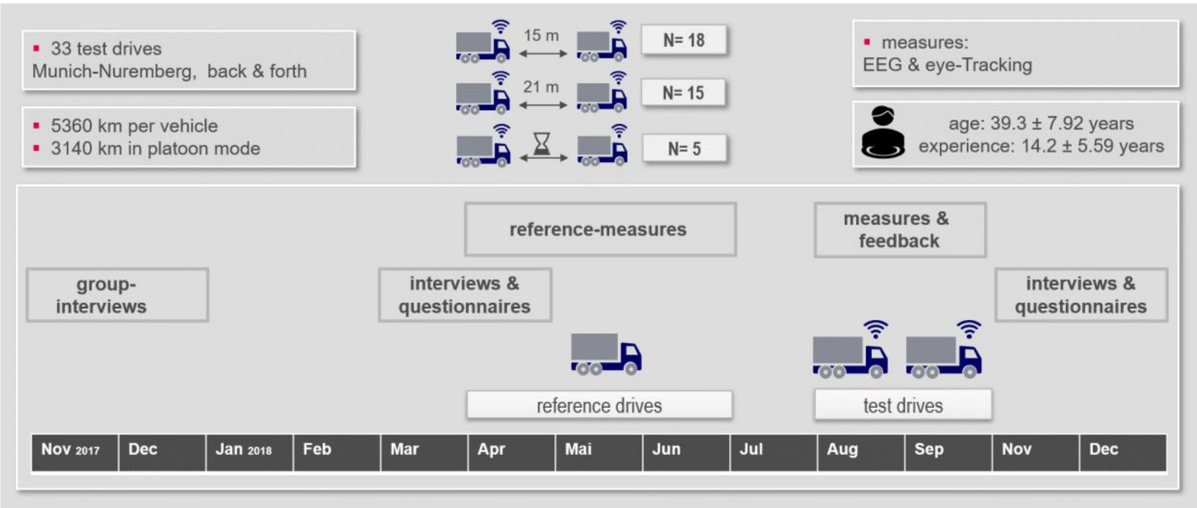


As such, DB Schenker started transporting actual goods with the platooning vehicles in mid-September. Incorporation into DB Schenker's standard operations allowed the cooperation partners to gain extensive insights into system reliability, the integration into mixed transportation as well as the practical suitability of truck platoons. As part of the pilot project, potential savings for fuel and emissions were also analyzed and measured. During the entire period, ten truck drivers were deployed, who also drive current scheduled services. In this way, the aim was to assess for the first time acceptance of the new technology among professional drivers.

The drivers: a study with technical measurements

Six academics from the Hochschule Fresenius accompanied all the drivers involved in the project over 13 months. During the journeys, they conducted neurophysiological measurements on the drivers, using electroencephalography (EEG) and eye-tracking. EEG picks up the voltage fluctuations on the head caused by the constant electrical change of state of brain cells. These brain currents are made up of different frequencies. Each frequency range in turn reflects different alertness and activation states. The raw data is broken down into the frequency bands using mathematical transformations. This facilitates the analysis of the driver's level of alertness and activation. The eye-tracking system consists of glasses, which record the individual's eye movements using several cameras. These movements can then be analyzed, including the gaze distribution, fixation period or areas of interest (AOI).

As part of the social science studies the academics conducted open interviews with truck drivers. Before the test phases, 23 drivers were interviewed in groups and the ten test drivers interviewed one-to-one on their choice of profession, profession characteristics and the assessment of the profession as well as on their assumptions in relation to the practicability, safety and consequences of the platooning technology. After the test phase, the participating drivers were asked in individual interviews to explain in detail their experiences in the test phase and questioned about their assessment of and possible improvements to the technology. All interviews were recorded on tape, transcribed fully and analyzed systematically. In addition, standardized questionnaires were used to measure the acceptance of and trust in the technology, subjective alertness and the safety-relevant assessment of specific driving situations before during and after the test phase.



Fuel-efficiently almost once around the globe

The distance between the terminals from Munich to Nuremberg is around 145 kilometers. Of these about 105 kilometers can be driven in platooning mode. In the pilot, the drivers in the Bavarian capital set off at 21:30 and returned from Franconia from 01:30. On average, they completed approximately 73 kilometers in the platoon for the outward/return journey. Weather-induced cancellations – platooning mode not permitted on a wet road surface – came to around 25 percent. Through November the weather was drier than average. Following completion of the runs on the Digital Test Bed of the A9 between Munich and Nuremberg, the engineers, logistics specialists and academics analyzed the extensive data and are now presenting their findings and insights. Overall, the platooning pilot drove almost once around the globe – clocking up 35,000 kilometers. The technology used in the MAN prototypes proved highly robust, with system availability of 98 percent. The driver had to override the system just 0.5 times every 1,000 kilometers. There were four planned breakups for the outward/return journey, plus two safety maneuvers due to communications constraints as well as on average less than one breakup due to vehicles cutting in. The pilot operation showed a fuel saving of three to four percent was possible in the following vehicle of the platoon compared with the reference value of an identical MAN TGX truck, which systematically uses all the very latest efficiency technologies. In the lead vehicle the same figure is around 1.3 percent. The pilot project restrictions and the mandatory breakups need, however, to be taken into account here. Furthermore, the reference vehicle uses additional fuel-saving technology (GPS cruise control Efficient Cruise 2), which could not be used for the platooning runs due to the stringent speed specification of 80 km/h. As such, it was not possible to efficiently use the coasting phases in platooning mode. Each breakup and safety maneuver also consumed around 0.1 liters of fuel. Consequently, additional optimization potential for platooning mode could be leveraged here under different conditions.

DB Schenker: 40 percent of driven kilometers in platooning mode

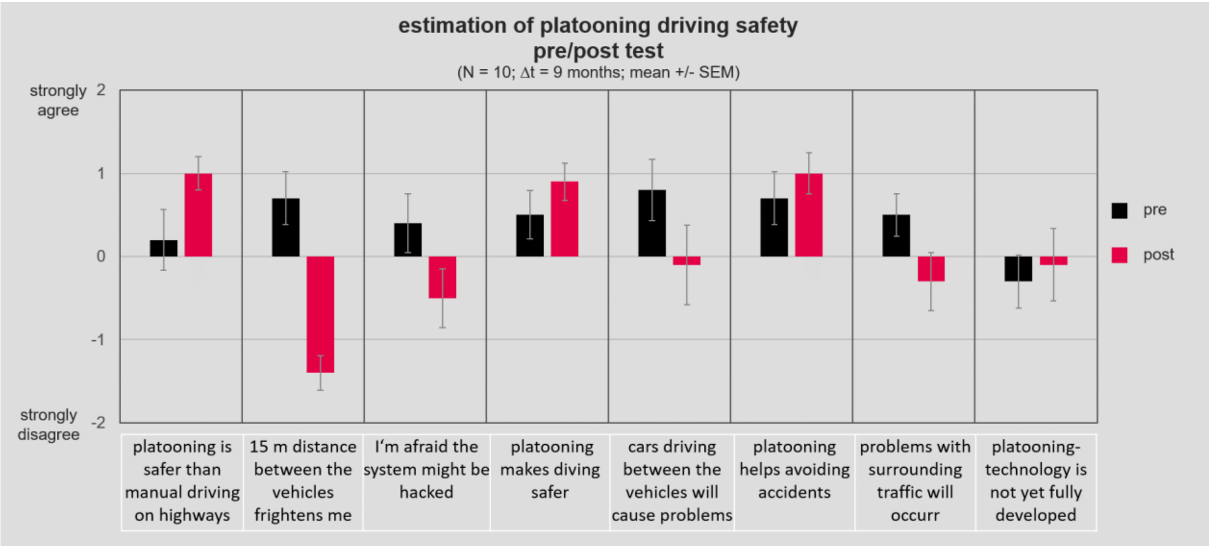
DB Schenker found that the platooning technology can be rolled out extensively in the groupage network. Around 25 percent of all connections include journeys that have at least another departure per day with the same destination terminal. The consignments can therefore be consolidated and implemented in platoons. Converted into distances this is equivalent to just under 40 percent of the driven kilometers. Additional potential emerges if other parameters are factored into the analysis: The departure times of the logistics journeys are in most cases so near to each other that it would also be possible to consolidate these journeys without excessive organizational changes and implement them in platoons. The platooning journeys could also be made if two vehicles have the same start and destination points at the same time which are located in a similar direction. This ensures the vehicles transport their consignments in the same direction, thus allowing routes to be combined. This is also significant insofar as groupage traffic at DB Schenker accounts for a substantial portion of land transport revenue.

Better infrastructure efficiency

The analysis of DB Schenker's own transport data highlighted highly utilized routes in the European network and especially in Germany. These routes involve the cross-border highways that run in an east-west or north-south direction. In the west of Germany transport volume is far higher than in the east of Germany. Bottlenecks already exist there on the main traffic routes, resulting in increased travel times for all road users and economic losses for society as a whole. Around 2,000 jams build up on German highways every day, costing car drivers around 80 billion euros a year in total – not to mention the drawbacks caused by longer and delayed delivery times within the haulage sector. Platooning can have a positive influence on traffic capacity. The reduction of the space needed for two trucks from around 90 to about 50 meters – with three trucks the same figure is cut from 155 to 80 meters – and the improved traffic flow due to automated driving will allow the infrastructure to be used more efficiently. A positive network for truck platoons could be set up to integrate the technology in stages into actual traffic. DB Schenker along with other transport sector businesses could bundle their activities in this way, observe the effects of autonomous driving technologies on road traffic and identify necessary areas of action for government, society and industry. This would reduce road traffic on main traffic routes in the near future and strengthen the economy.

Improved road safety

Heavy traffic congestion is currently a significant risk factor on German highways. According to the Federal Ministry of Transport and Digital Infrastructure, human error is responsible for 90 percent of traffic accidents. The number of accidents involving trucks continues to rise every year. The most frequent cause is insufficient distance between vehicles. Measurements on German highways have shown that a major proportion of trucks undershoot the safe distance by a large margin at a speed of 80 km/h. Linking trucks electronically increases road safety as they respond as a single unit. If the first truck brakes, the other trucks linked in the platoon brake virtually simultaneously. The human response time is eliminated. Safety is also increased for the surrounding traffic as the platoon mode requires the use of the adaptive cruise control (ACC) in the lead vehicle. The ACC constantly maintains the legal minimum distance of 50 meters to vehicles driving in front of the platoon and reduces the speed accordingly where necessary. If, however, an imminent rear-end collision with vehicles ahead or stationary vehicles is likely, the emergency braking system, such as the MAN EBA2, brakes the platoon to a stop where necessary. Safety and driving comfort are also the key advantages of platooning from a driver perspective. Hands-on experience in the cab has shown a substantial change in driver attitudes. Before the test drives, the drivers were still expressing – in some cases considerable – doubts



about safety and the technology. They also assumed that stress would increase, in the front vehicle due to the increased responsibility, in the following vehicle due to the shorter distance and the exacting requirements placed on concentration. After the runs, all the test drivers explained that they got used to the technology and distance right from the training drives and very quickly began to trust the technology. The system response time was described as follows: "As soon as I saw the brake light of the vehicle in front, the vehicle behind responded or braked. As a human, I wouldn't even have managed to take my foot off the accelerator." According to the experience of the test drivers, the workload in the front vehicle is slightly higher, as there is the need to "also think about" the following vehicle. Most of them describe driving in the following vehicle as relaxed. In the overall assessment, the platoon's safety is assessed as "clearly higher" than conventional truck driving. It must be remembered with these statements that the project restrictions meant the trucks were not linked for more than 30 minutes due to the route and platooning was not permitted in adverse weather conditions – such as a wet road surface.

Short vehicle distance perceived as "agreeable"

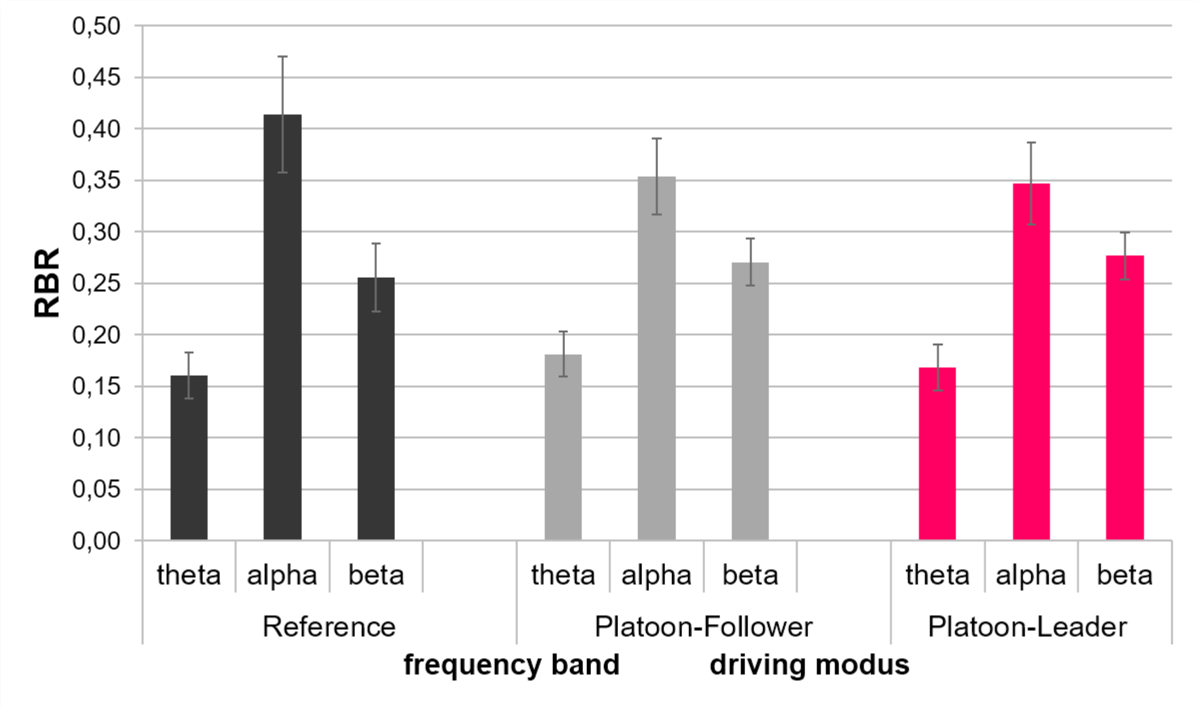
A general sense of safety and trust in the technology is echoed in the drivers' assessment of specific driving situations. None of these situations is referred to as uncontrollable. The following situations were regarded as critical on one occasion respectively, even though they could be controlled: broken down vehicle in the breakdown lane, overtaking truck with heavy load, emergency braking as well as a driver steering error. The drivers perceived vehicles cutting in or vehicles crossing several lanes on average as "disagreeable", even though this was not seen as a safety risk since the system responds, according to their statements, reliably by breaking up the platoon to increase the distance. They described their experience roughly as follows: "A vehicle cutting in, rather than a car cutting in not (quite) half a meter in front of me, it's now cutting in two meters in front of me, then it's no problem. The whole thing still brakes wonderfully, releases the brakes, whatever. Does the job." More vehicles cut in every 1,000 kilometers when the distance between the vehicles in the platoon is 21 meters.

Reducing the distance to 15 meters results in fewer vehicles cutting in. Whereas the distance in the platoon before the runs was still seen as a major source of risk, the drivers felt a distance between 15 and 21 meters in over 90 percent of the platoon times was "agreeable." Today they would even prefer to reduce the distance to less than 15 meters. One driver explained in this respect: "When it comes to vehicles cutting in, cutting across several lanes. From experience you simply know that there's less going on at 15 meters than at 21 meters. That's why I'd prefer 15 meters. I'd even go down to 12."

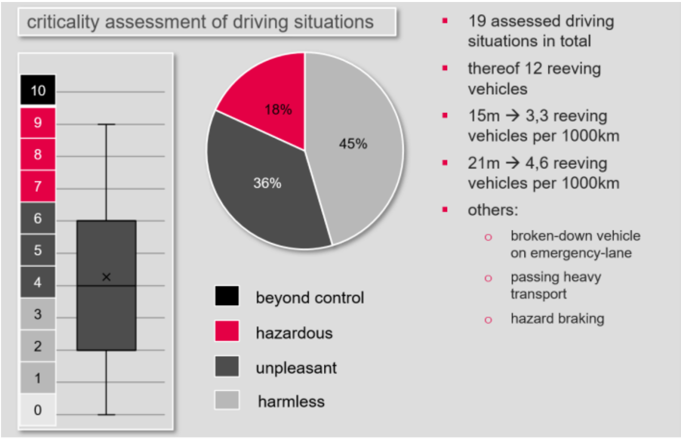
This familiarization process may well be a decisive factor in a noteworthy phenomenon: Having broken up the platoon, it was apparent that temporarily – for twelve minutes on average – a shorter vehicle distance was maintained in 25 percent of the runs. Afterwards, the distance behavior once again got back closer to the initial state of the 50 meters prescribed by law. To prevent this phenomenon in future, the drivers' attention should be drawn actively to this response during training and this aspect practiced specifically where necessary. A distance warning system could also help drivers maintain a sufficient distance after platoon phases.

EEG and eye-tracking measurements with few anomalies

The EEG measurements showed no systematic differences between platoon runs and normal runs when it comes to the neurophysiological stress placed on drivers. This applies to lead and following vehicles alike.



Caption: The figure shows the relative proportion of the various frequency bands in overall brain activity. A change in the proportions of the frequency bands is associated with a change in the alertness state or the activation. The physiological EEG includes frequencies of each band component. The three main relevant frequency bands are shown: theta, alpha and beta in the different drive modi.
Theta activity occurs increasingly with drowsiness and in the transition to sleep. Alpha activity represents the state of physical and mental relaxation, while beta activity reflects a state of physical and mental exertion and concentration. There are no systematic differences between the three drive modi with the overall analysis of the brain.



As part of the eye-tracking studies, the relative gaze distributions on the windshield, display and side mirrors were analyzed. Between the reference and the platoon runs there were no major differences in terms of the frequency of the gazes and the gaze direction. There was, however, the tendency for the speedometer to be viewed more frequently in the lead truck than in the following truck and with a normal run. Since the following truck is only visible to a certain extent in the mirror, the display of the driving data provides the most important source of information on the handling of the platoon partner. The greater tendency to look at the speedometer is therefore understandable and accounts for the slightly higher workload on the front driver. In takeover situations, drivers also took their eyes off the traffic situation for longer periods in some cases. These, however, did not last longer than two seconds on average. To prevent the driver from increasingly looking at the speedometer in future, the information on the following truck could be presented in a different way - for instance via a head-up display built into the windshield.

Platooning and the future of the professional driver

When asked about the impact of platooning on the truck driver profession, many interviewees expressed concern about jobs before the test runs. One driver sums it up aptly: "And two trucks means with one driver. Where is the second driver? At the job center." A similar fear was expressed that the requirements placed on drivers will be reduced and, in turn, the image of the profession tarnished - "You could - to be fatuous - put anyone in the cab. (…) Here, you get a truck license, climb into the cab, the thing drives by itself, you don't need to be able to drive it." – or cuts in salary are the consequence: "You do half the work, so you no longer need such a big salary. Because all you do is sleep from here to Hamburg."

During the course of the project the test drivers realized that platooning does not aim to replace drivers, but to reduce their workload. The personal benefits are assessed positively, since platooning is regarded as more comfortable and more relaxed overall than driving manually. Nine out of the ten test drivers would use platooning if their employer were to offer it. The drivers no longer assume that platooning threatens driver jobs, but tasks will be changed and in some areas become more challenging and more interesting. Here an opportunity is also seen to combat the shortage of professional drivers: The technology could make the profession more attractive to young people. At the same time, platooning enhances career opportunities within the profession. Occupational research has already shown that development opportunities are a relevant factor in a profession's attractiveness and satisfaction.

Conclusion and outlook

Technological and collaborative further developments may in future increase further the potential of truck platooning. Multibrand platooning, ad-hoc or on-the-fly platooning and multicompany platooning are just some of these options. However, new concepts will also be necessary to introduce the technology and optimize the business model. New digital business models are also conceivable through platooning, which could substantially increase the efficiency and revenues for logistics service providers. The number of platooning-capable haulage consignments and the kilometers that can be driven in platooning at DB Schenker are good prerequisites for integrating the technology into scheduled operations and increasing the cost-effectiveness of the haulage processes. Platooning can also be seen as a preliminary stage to autonomous driving and help implement autonomous technologies earlier into road traffic.

Platooning will bring about a substantial change in the image of the truck driver profession. Automation in road traffic will shift the drivers' role from driving to monitoring. The "truck driver" will in future become a "platooning pilot." The sphere of responsibility of the lead driver will increase. Both drivers could potentially see their workload reduced – with higher levels of automation. The necessary higher level of training may enhance the professional driver's image; the experience with the technology may increase the acceptance and usage of new digitalization solutions.

In light of the acute shortage of drivers, which is immediately apparent to most companies, the industry currently faces major challenges. In particular, the age structure of professional drivers, the abolition of compulsory military service and the prestige and reputation of the profession are some of the root causes of the shortage of qualified operating personnel. In this respect, the financial repercussions for businesses are substantial in terms of training, onboarding and further employment of drivers. In addition, the number of suitable applicants for jobs in logistics is falling due to the unattractive working conditions and the low number of qualified personnel. In future, the age structure of drivers is set to further exacerbate the problem of the driver shortage. The repercussions are limited not just to the haulage and logistics industry, but also to society as a whole. For these reasons, measures are required to improve the attractiveness and the future prospects of the professional group, which are regarded as key points of criticism of the industry at present. The surveys before, during and after the test phases show that the platooning technology is accepted positively once drivers have used it. Against the backdrop of improving the image of the profession, autonomous driving therefore offers opportunities to improve this image. Despite automation in road traffic, the driver will indefinitely remain a key component of transportation logistics.

The findings of the research project set an important milestone on the road to autonomous driving. Key advantages of truck platooning have emerged. To classify the academic findings adequately, the boundary conditions of the study need to be included, such as the number of test subjects, the route characteristics and the length of phases in platooning mode. To be able to make additional general statements, further studies will need to vary the boundary conditions, including the weather conditions. It appears worthwhile in particular to verify the impact of extended platooning phases. Possible activities in the follow-up vehicle not related to the task of driving also form part of a broader investigative approach. New regulations must provide the conditions for all this.

Partners in the project

MAN Truck & Bus SE

MAN Truck & Bus is one of the leading European commercial vehicle manufacturers and a provider of transport solutions with annual sales of around EUR 11 billion (2018). The product portfolio includes vans, trucks, buses, diesel and gas engines, as well as passenger transport and freight transport services. MAN Truck & Bus is a TRATON SE company and employs more than 36,000 people worldwide.

As a commercial vehicle manufacturer that is innovation-led, MAN contributes to the project its expertise in the field of vehicle automation. MAN therefore made a major contribution to the project in the areas of system development, system testing and user training. Based on the insights from previous projects, MAN developed a platooning system for the robust operation in actual traffic to implement the pilot. This was implemented in three vehicles which will be provided for the pilot. As the manufacturer of the vehicles, MAN is tasked with conducting tests to verify system reliability, as the basis for special approval of operation on public roads as part of the project. During standard operation, MAN ensured the technical supervision of the test vehicles and conducted driver training.

DB Schenker

DB Schenker is Deutsche Bahn AG's transportation and logistics subsidiary, supporting industry and trade in the global exchange of goods: in land transport, worldwide air and ocean freight, contract logistics and supply chain management. With some 22,000 employees at 730 locations, DB Schenker is the number one in European land transport. The business unit connects the key economic regions and around 40 European countries with a network of around 32,000 scheduled services for groupage per week. As the largest provider in European land transport, DB Schenker has extensive knowledge of the specific requirements of land transport consignments and leveraged this expertise to specify the project accordingly. As such, DB Schenker made an important contribution to ensuring that the requirements from an end-user perspective, the logistics provider, are met when developing platooning systems.

DB Schenker assumed the role of project coordinator. The relevant project members from DB Schenker already have extensive experience of managing joint projects. For instance as part of supervising university joint ventures.

Hochschule Fresenius

The Hochschule Fresenius with its campuses in Berlin, Düsseldorf, Frankfurt am Main, Hamburg, Idstein, Cologne, Munich and Wiesbaden and Study Center in New York with its 13,000 students ranks among the largest, most renowned private universities in Germany. It can look back on more than 170 years of tradition. Carl Remigius Fresenius founded the "Chemical Laboratory Fresenius" in Wiesbaden in 1848, which was dedicated from the outset to both laboratory practice and education. The University received government recognition in 1971. It covers a wide, varied range of subjects and offers full-time, part-time bachelor and master programs in Chemistry & Biology, Design, Health & Social Affairs, onlineplus and Economics & Media, along with dual-study courses. The Hochschule Fresenius is accredited institutionally by the Science Council. As part of its initial accreditation in 2010, the Science Council singled out in particular its "broad and innovative range of bachelor and master courses," "its international outlook" and its "compellingly designed practical orientation." In April 2016 the Science Council re-accredited it for another five years.

The University's Institute for Complex System Research is an interdisciplinary research unit looking at, among other things, human-machine interfaces. Biomechanical, neurophysiological and mathematical as well as psychological–social scientific investigation methods are used. Numerous past and present projects relate to the field of "Transport and Logistics" and have been based organizationally in the House of Logistics and Mobility (HOLM) Center of Excellence since 2014.

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